Stanford

Quarterly Status Report No. 11

NASA Contract NASr-136

for the period

July 1, 1965 through September 30, 1965

1. Operation

In view of the power shortage aboard the S-49 satellite during the period covered by this report, the radio beacon experiment could not be turned on and consequently no measurements were made.

2. Data Analysis

Technical Report No. 1, prepared under the present contract, entitled "Eccentric Geophysical Observatory Satellite S-49, Interpretation of the Radio Beacon Experiment", (DA ROSA [1965]) has been published and a copy is attached to this report. It describes the details of the reduction technique used to transform the raw data received from the two beacons on the satellite into curves of ionospheric and esopheric columnar content vs. time.

At present twenty of the most useful Stanford runs as well as two from Athens have been completely reduced.

3. Results

A paper, the summary of which is attached, describes some of the experimental results from work done under this contract. It will be read at the Second Symposium on Radio Astronomical and Satellite Studies of the Atmosphere in Boston, Massachusetts, on October 20, 1965.

In order to better understand the phenomena that occur in the dawn ionosphere and which reveal themselves through the data collected from the S-49 radio propagation experiment, it was necessary to study the theoretical time-dependent thermal behavior of the ionospheric electron gas. This problem leads to a second order, non-linear, partial differential equation that was numerically integrated with a digital computer. Interesting results were obtained, such as the prediction of the early morning peak in electron temperature observed experimentally. This study will be included in a second technical report presently being prepared.

Attch: 2

Summary of

# RESULTS FROM THE RADIO BEACON EXPERIMENT ON THE ORBITING GEOPHYSICAL OBSERVATORY

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The S-49 satellite, launched on 5 September 1964, carries a pair of radio beacons operating at harmonically related frequencies which permitted the simultaneous measurement of columnar electron content by the differential Doppler frequency and the Faraday rotation angle techniques. As it is well known the difference between these two measurements can be interpreted as the columnar content of the exosphere up to satellite heights. The very eccentric orbit of the spacecraft with an apogee of nearly 150,000 km allowed the observation of a good part of the near exosphere.

The technique used in reducing the received data was described by DA ROSA [1965].

Interpretation of the data leads to conclusions in the following areas:

a - Dawn Exosphere Seven Ego runs straddled the sunrise hours and in four of them the exosphere content showed a behaviour similar to the one represented by the 29 March, 1965 curve in the figure, in which the nighttime columnar content was very steady (the rise at the beginning of the run is due to the high recession velocity of the satellite, right after perigee). As the sun starts illuminating the higher atmosphere (zenithal angle of some 96 degrees) both the Doppler and Faraday contents (not shown) start rising so that the difference (exosphere content) remains stationary except for some small oscillations. At a zenithal angle of about 87 degrees the Faraday content suddenly starts to decrease only to resume its climb some 20 minutes later. The Doppler content during this period keeps a steady climb, resulting in a very fast growth of the exosphere content, which could be interpreted as a flux, into that region, of the order of $10^9$ electrons. $cm^{-2}.sec^{-1}$. The delay between sunrise and the instant of rapid increase in exosphere content varies from day to day, being as short as 20 minutes in one case and as long as 90 minutes in another. The duration of the exosphere growth is also variable but is of the order of 30 minutes. It may be that in the three days when this growth was not observed, it was delayed beyond the period of observation which sometimes did not extend too far into the morning hours. Syncom III observations show that this "break" in the Faraday content curves is the rule rather than the exception. Theoretical models to explain the phenomenon are still under study.

It is also observed that in some of the mornings there is a marked increase in the slab thickness of the ionosphere due to a reduction in the value of $F2_{max}$ observed with an ionosonde. Since theoretical investigations show that the plasma temperature can increase considerably under the influence of the rising sun, before substantial changes in the degree of ionization can occur, it is clear that the resulting scale height change may cause the available ionization to flow up from the lower ionosphere thereby reducing the concentration near the peak.

b - Exosphere concentration. The observed changes in columnar electron content in the exosphere as seen from the Ego data may be due to one of the following features:

- The radial motion of the satellite which causes an increasing amount of ionization to be included in the ray path. From this, local concentrations could be derived.
- The tangential motion of the satellite which reveals horizontal gradients in the exosphere.
- Temporal changes in the exosphere.

In interpreting the dawn data it was assumed that the first two effects were negligible due to the smaller radial velocity when the spacecraft is several hours out of perigee, combined with the expected low local concentrations and by virtue of the small angular velocity of the satellite.

Early in the pass, specially at night when only small temporal variations are expected, it is possible to attribute the columnar content variations to the first two effects alone. Very large horizontal gradients are revealed by the fact that, in many runs, the exosphere content seems to decrease as the satellite rises, due to the fact that the exosphere concentration is much larger within the magnetic shells defined by the position of the knee than outside. As the satellite appears to move north when it rises from perigee, the ray path will intercept less and less of this more densely populated volume of the exosphere and the observed columnar content decays.

The geometry of the satellite motion is such that in certain parts of certain runs the effect of horizontal gradients is minimized while there is still considerable radial velocity. Local concentrations can then be inferred. This has not been done yet in detail, and for this reason no values can be quoted here.

c - Nighttime F - Layer. The very steady value of the nighttime columnar contents seen in most of the Ego records suggested a statistical investigation for which the very extensive catalog of diurnal variations of columnar ionospheric contents obtained from Syncom III (GARRIOTT, SMITH and YUEN [1965]) was used. A total of 83 runs from Stanford and 154 from Hawaii were examined and classified as

- FLAT Runs in which there is no perceptible change in columnar content between midnight and sunrise.
- DECLINING Runs in which the content declined monotonically
- RISING Runs in which the content rised monotonically.
- IRREGULAR Runs not in any of the above categories.

It was found that 53% of the Stanford runs were "flat" and 18% "declining," whereas in Hawaii the order was inverted (15% "flat" and 48% "declining"). The "flat" nights at Stanford were associated with average Kp indices substantially lower than the mean for the period (1.21 versus 1.66) while "declining" nights corresponded to high average Kp (2.81). No such effect was found for Hawaii.

These results can be interpreted by assuming that the nighttime ionosphere is maintained by a cooperation of the two processes most frequently proposed to explain the phenomenon: the appearance of vertical drifts that reduce the effective recombination rate and the downward flux of electrons from the protonosphere. That a nighttime source is required can be seen from the existence of "rising" and "irregular" nights (in the latter, humps in the columnar content vs. time curve, appear frequently). HANSON [1964] computed fluxes of the order of $10^8$ electrons. $cm^{-2}.sec^{-1}$ as necessary for the maintenance of the nighttime ionosphere. Calculations made by ANGERAMI and CARPENTER [1965] based on whistler data, yield values of tubular content of the protonosphere (between 1000 km and the equator) which, when extrapolated to the latitude of Hawaii and Stanford indicate that one may expect contents of the order of $10^{12}$ and $3 \times 10^{12}$ electrons. $cm^{-2}$ at, respectively, these two stations. The lower content is clearly insufficient to maintain the ionosphere for more than some two hours and should, as it is actually observed, result in nights in the "declining" category. At Stanford the content is larger and "flat" nights should be, and are more frequent.

CARPENTER [1962] observed that the protonospheric electron concentration inside the "knee" is depressed when there is an increased geomagnetic activity; this would explain the effect of Kp on the Stanford statistics. At Hawaii, even in a quiet night there are in general not enough electrons in the protonosphere to supply the ionosphere, so the geomagnetic effect can not make itself felt. It is to be expected, on the basis of this theory, that for stations with ionospheric points at around L=3 or L=4 there should be a sharp change between "flat" and "declining" nights when the Kp increases the "knee" moves in, changing markedly the available supply of protonospheric electrons.

SMITH [1960] observed annual variations in protonospheric concentrations. This appears also to be reflected in the present data by the fact the frequency of "flat" nights at both Hawaii and Stanford, diminished by a factor of two between the end of 1964 and the middle of 1965.

If the cause of "declining" nights is the depletion of the protonosphere at low latitudes and beyond the "knee", then one would expect to find a more pronounced diurnal variation in the protonospheric concentration at these latitudes than at those immediately inside the "knee". This seems to be, at least partly, substantiated by ANGERAMI and CARPENTER [1965].

Bibliography

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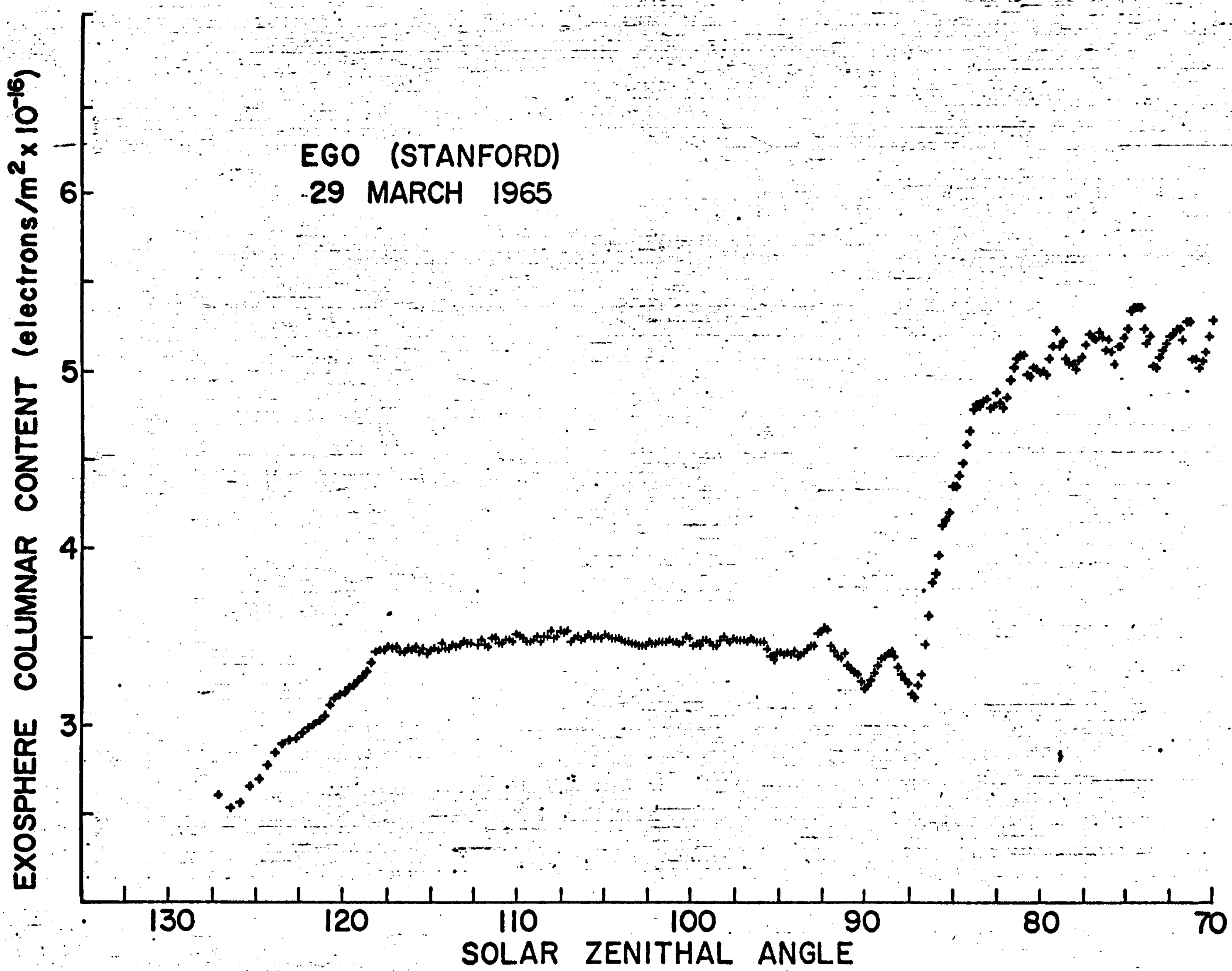

EGO (STANFORD)
29 MARCH 1965
EXOSPHERE COLUMNAR CONTENT (electrons/m$^2$ x 10$^{-16}$)
6
5
4
3
130
120
110
100
90
80
70
SOLAR ZENITHAL ANGLE